Evaluation of GEOS-5 PBL and Aerosols During DISCOVER-AQ

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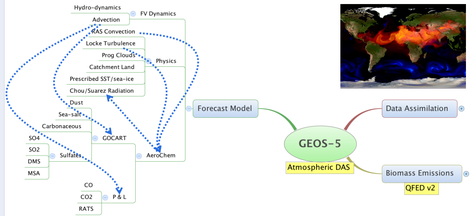
Abstract

GEOS-5 is the latest version of the NASA Global Modeling and Assimilation Office (GMAO) earth system model. GEOS-5 contains components for atmospheric circulation and composition (including data assimilation), ocean circulation and biogeochemistry, and land surface processes. In addition to traditional meteorological parameters, GEOS-5 includes modules representing the atmospheric composition, most notably aerosols and tropospheric/stratospheric chemical constituents, taking explicit account of the impact of these constituents on the radiative processes of the atmosphere.

The overarching goal of DISCOVER-AQ is to better understand the processes that relate column averaged measurements of atmospheric constituents by satellites to near surface air-quality parameters. While statistical methods can provide useful co-relative information on the subject, assimilation of satellite observations into comprehensive earth system models holds the promise to unravel the mechanisms involved.

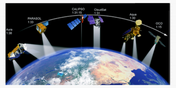
In this study we use measurements collected during DISCOVER-AQ to evaluate the GEOS-5 vertical structure of aerosol extinction. Initial diagnostic of the NRT GEOS-5 indicated an overly deep Planetary Boundary Layer (PBL) height, tracing back to a precipitation deficit in the preceding season, leading to a hot and dry land surface. Correcting the soil moisture and prescribing observed precipitation improved the Bowen ratio and lead to better near-surface temperature, PBL height and aerosol vertical distributions.

GEOS-5 at a Glance



Aerosol Data Assimilation

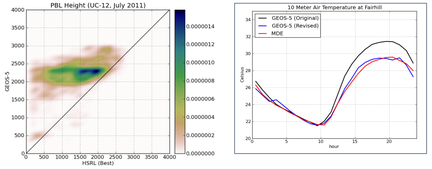
- Focus on NASA EOS Instruments



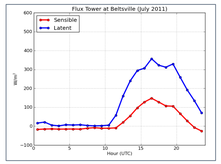
- Global, high resolution AOD analysis
  - Nominal 25km resolution
  - 3D increments by means of Lagrangian displacement ensembles
- GEOS-5 is driven by NRT biomass emissions derived from MODIS Fire Radiative Power.
- The GEOS-5 Aerosol Assimilation System (GAAS) ingests NRT radiances from MODIS on Aqua/Terra platforms
- Measurements are calibrated and bias corrected using historical AERONET in-situ measurements as reference.
- OMI UV aerosol index are simulated using a detailed radiative transfer calculation and used for validation.

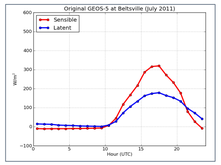
Hot and Dry Land, Deep PBL

Initial evaluation of the NRT GEOS-5 indicated a very deep PBL

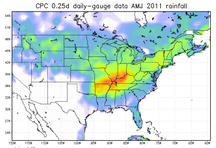


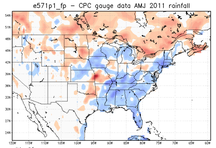
Examining flux tower measurements at Beltsville exposed a problem in GEOS-5 sensible and latent heat fluxes:



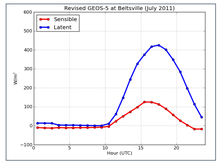


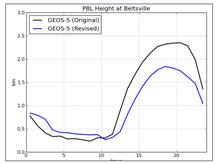
Single-column experiments and further diagnostics pointed us towards a dry land in response to a precipitation deficit in the Spring:

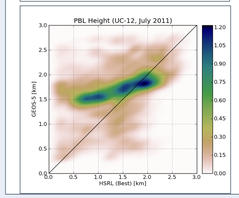


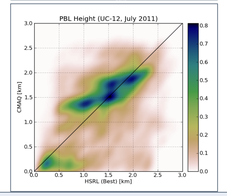


Prescribing observed precipitation and starting from a revised land surface initial condition (from MERRA) had a positive impact:



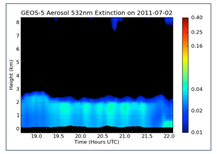


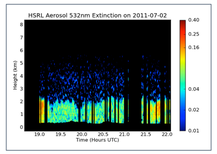


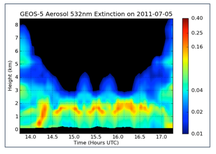


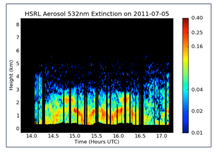
HSRL Extinction Profiles

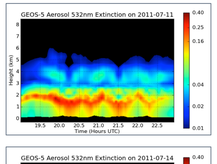
GEOS-5 Extinction Profiles have been simulated for all HSRL Flights

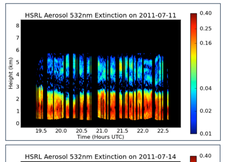


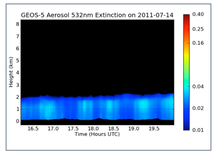


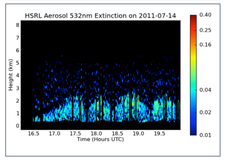


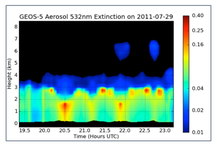


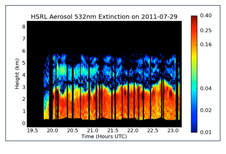










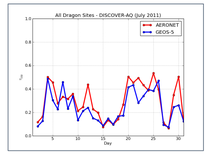


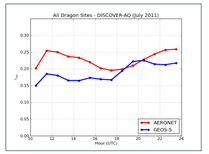
Each of these profiles have been interpolated to the HSRL in time and space from GEOS-5 3-hourly extinction profiles.

- GEOS-5 is able to capture the day-to-day variability in aerosol extinction
- GEOS-5 derived extinctions are generally smaller than HSRL's
- GEOS-5 successfully captures aerosol layer above PBL on the 11th
- There is evidence of excessive mixing at the beginning and end of the flight on 5th, suggesting too much convective transport.
- GEOS-5 extinction tend to peak at top of PBL, while HSRL indicates a more uniform mixing in PBL on the 11th and 29th.

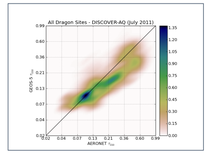
DRAGON

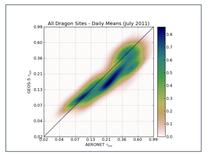
GEOS-5 derived Aerosol Optical Depth (AOD) has been interpolated for each of the 17 AERONET "DRAGON" stations. GEOS-5 is able to capture the day-to-day variability in AOD, in somewhat mimics the modest diurnal cycle:



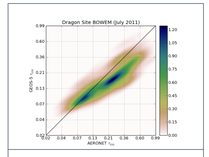


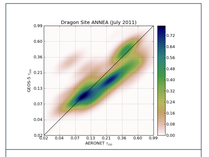
On a measurement by measurement basis, GEOS-5 tend to under estimate AOD, more so in earlier part of day.

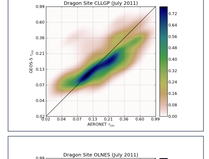


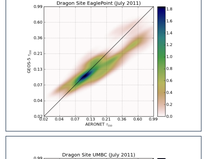


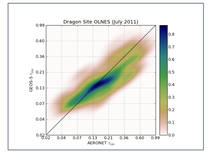
There is a relatively small change in the GEOS-5 among the different DRAGON station, all of the suggesting underestimation around 0.3.

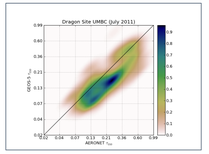






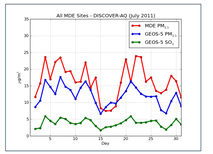


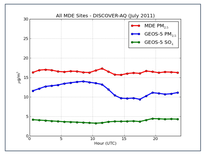




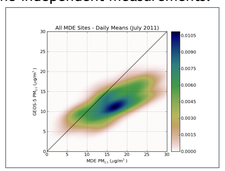
PM 2.5

We have evaluated the GEOS-5 derived PM 2.5 surface concentrations at 4 MDE stations (Beltsville, Edgewood, Fairhill and Old Town.) GEOS-5 is able to capture the day-to-day variability in PM 2.5, although it tends to underestimate by ~30%. GEOS-5 also tend to have a more active diurnal cycle. Carbonaceous aerosols were the main contributors to the PM 2.5 concentrations reported by GEOS-5





On a station by station basis, GEOS-5 daily mean estimates are highly correlated with the independent measurements:



Concluding Remarks

We have evaluated aerosols and PBL heights using data collected during the DISCOVER-AQ campaign. Despite the relatively coarse resolution of GEOS-5 (~25 km) it is able to faithfully capture the vertical structure and day-to-day variations in AOD and PM 2.5, although it generally underestimates its magnitude. Although MODIS AOD is being assimilated, the twice daily data availability is not sufficient to constrain the model throughout the rest the day.

PBL height data from HSRL has been crucial for diagnosing issues with the land surface in the NRT GEOS-5 system. The remaining overestimation of PBL heights can in part explain biases in PM 2.5.

Future Work

The following activities are being considered for extending this work:

- Further analysis including airborne, sondes and ground-based LIDAR measurements.
- Extend GEOS-5 OMI simulator for ACAM data.
- Evaluate GEOS-5 derived CO and SO_2
- Revision of the GEOS-5 anthropogenic emissions which now consists of out-of-date annual mean inventories.
- Assimilation of GOES derived AOD retrievals in order better constrain GEOS-5. J. Stehr (AGU 11 talk) has shown that GOES AOD retrievals performed very well during DISCOVER-AQ.
- A higher resolution simulation (~10km) using the non-hydrostatic GEOS-5 on the cubed-sphere.